The Department of Conservation and Land Management
CALM**Science** Division

# FORESTCHECK

## AN INTEGRATED SYSTEM FOR MONITORING THE FORESTS OF SOUTH-WEST WESTERN AUSTRALIA

Concept Plan prepared by CALM Integrated Forest Monitoring System Implementation Group

May 2000

## Executive Summary


1. ESFM is well defined at a policy level but remains an ill-defined scientific concept.
2. FORESTCHECK is a framework devised in 1999 to quantify, record, interpret and report on the status of key forest organisms, communities, and processes in response to both forest management activities and natural variation.
3. A CALM Implementation Group has been established to guide the development and implementation of FORESTCHECK.
4. The most desirable attributes have been identified as simplicity, integrated sampling, efficient sampling, reliability, feasibility, credibility and affordability. It is recognized that it is not possible to optimise all of these traits simultaneously.
5. Monitoring is treated as a form of quality control. FORESTCHECK is not a substitute for audit, compliance, survey or research.
6. FORESTCHECK has been designed to mesh with the Montreal Process Criteria and Indicators (agreed to jointly by the Commonwealth and State Governments in 1998).
7. This concept plan has been workshopped within CALM (April 1999) and with scientists from universities, CSIRO, and the WA Government, as well as scientists privately employed (October 1999, March 2000).


## Introduction

Monitoring, audit, compliance and research are terms widely used at present in corporate governance in Australia. The first three concepts refer to the checking process in the sequence PLAN - ACT - CHECK. Audit until recently referred to the official examination and verification of (orally presented) financial accounts by an independent body. It is often used now to refer to independent verification of any matter, particularly systems in place. Compliance refers to the need to check how well an action adheres to stated policies, prescriptions, codes of practice etc. Monitoring is also a form of quality control, but includes the concept of testing at intervals. By contrast, research alludes to systematic and critical investigation to discover facts and reach novel conclusions and thereby create new knowledge. Scientific research is generally pursued within a framework of formulating and testing a set of hypotheses. It is important to recognize that monitoring, while methodical, is neither scientific research nor a substitute for it. Nevertheless, monitoring is underpinned by scientific knowledge and its results may assist in the generation of hypotheses; these can then be addressed using scientific methodology.

Because knowledge about disturbance ecology is incomplete, monitoring is likely to generate data that are open to interpretation in some cases. Expert scientists can contribute to the interpretation of the data acquired. Ultimately, it is most important that the forest owners, the Western Australian community, understands and accepts the consensus of expert opinion, and takes this into account when making social and political decisions about ESFM.

ESFM includes delivery of economic, social and environmental outcomes, Environmental monitoring via FORESTCHECK is just one aspect of the ESFM process. Collectively, these three components will facilitate changes to forest management practices so that the community obtains from forests what it seeks.

Monitoring in the southwest forests of WA commenced in 1916, with the establishment of plots to measure growth rates of trees. Other significant events in monitoring focused on mammals and fire impacts (1972). These and others are itemized in Attachment 1.

Compliance and monitoring are not new concepts, as evidenced by the venerable learning technique of trial-and-error (involving an action, then its assessment, followed by correction if an unwanted outcome resulted). The main difference between trial-and-error learning and more sophisticated versions lies in the degree of formality involved with the latter. Expected outcomes will be declared from the beginning in a written plan, there will be records of what actions were undertaken and when, where and how they were done. After implementation, there will be written records of how well the action was performed in relation to the declared expected outcome. If all proceeded 'according to plan' there is no need for corrective action and the principle of 'management by exception' is followed. If, however, there are 'surprises' (unexpected outcomes) or failure (the expected outcome wasn't produced), the planning process has to re-commence. The process is necessarily iterative.

This approach has become subsumed in the last 20 years under the concept of adaptive management, in which management interventions are regarded as hypotheses to be tested by implementing the planned action and following up subsequent events ('learning by doing').

In 1988 CALM approved a formal monitoring policy. This, however, proved unimplementable because of logistic reasons, resource limitations and lack of an agreed focus in the policy. It was formally withdrawn subsequently.

The current Forest Management Plan (LFC 1994) also committed to use of monitoring (pp. 51-52):

> *Implicit in the undertaking of management action is the need to monitor the implementation and impact of those operations. Monitoring is important across the full range of management actions, e.g. use of a recreation site or how closely a burn achieved its prescribed intensity, because through it the success of meeting forest management objectives is evaluated and the opportunity to upgrade prescriptions is presented.*
>
> *CALM's research programs also provide continuous input to the management process. The research programs are periodically adjusted to ensure they are providing information of the most important strategic value.*
>
> *At the most fundamental level CALM's forest management objective is to preserve biological diversity and the ecological processes which sustain that diversity. Monitoring to check if that is being achieved is difficult, because natural changes in ecosystems interact with those caused by management-related disturbance and because the large number of ecosystem components all react differently. A comprehensive monitoring program will encompass three components of ascending complexity, as follows:*
>
> ***(a) Monitoring the effectiveness of measures to protect the environment***
>
> *Codes of practice are the guidelines used to control forest operations in the field. They set standards and measures of performance for activities and operations conducted by CALM, contractors and other users of public forests.*
>
> *These codes aim to ensure that the people carrying out a forest operation such as road construction, tree planting, timber harvesting or recreation site maintenance complete it to the highest standard existing knowledge allows. They therefore constitute current best available practice.*
>
> *"Codes of practice" collectively describe a range of documents including manuals, prescriptions, specifications, standards and Guidelines. The codes are one of the instruments used to set standards for forest operations. Acts of Parliament, regulations, policies and contracts are other instruments used for this purpose.*

*CALM uses codes of practice for each of the major activities and operations conducted in the forest regions. Codes are reviewed and re-issued annually to reflect the results of the year's monitoring, or new research information.*

*Responsibility for implementing the codes is assigned to CALM's regional and district staff, assisted as necessary by specialist branches. Specialists and regional staff also have a role in ensuring that prescriptions are correctly followed in the field.*

***(b) Monitoring the impact of disturbance-causing activities.***

*In CALM this is carried out primarily through the Department's research program. Clearly, all species of the biota cannot be studied, and research is concentrated on what are believed to be keystone species.*

*Species known to be rare or under threat are given special emphasis in research, and in operational planning procedures. Threatened flora management programs will be progressively developed and implemented.*

***(c) Monitoring ecosystem change through periodic measurement of an extensive system of permanent plots and selected vertebrate and invertebrate species.***

*This is the most sophisticated level of monitoring because, if done adequately, it measures baseline ecosystem health and can detect management-induced change or natural environmental changes. It is, however, very difficult because:*

- *it requires considerable initial research to obtain a good dataset of regional biota;*
- *a large number of plots must be established and enough organisms sampled to ensure environmental diversity is covered.*

*Within the forest regions (a) is implemented, (b) partly implemented and (c) yet to be initiated. As resources allow, the monitoring program will be steadily upgraded through sophistication of (b) and, finally, full implementation of detailed ecosystem monitoring.*

In recent years these impediments have been largely resolved because of significant advances in technology, information and concepts.

First, the tool of GIS has become more sophisticated and also more readily available as a result of huge increases in computer capacity.

Second, the information base for the southwest forests has greatly expanded, largely because of the Regional Forest Agreement process. All available fundamental data have been captured electronically (with one major exception, fire history, currently being addressed).

Third, the conceptual distinctions between strategic research, prescription, and monitoring have become clearer. The strong conclusions from soundly-based research when incorporated into prescriptions obviate the necessity for frequent or detailed monitoring. This permits better deployment of available resources so that time and money are not wasted on documenting the obvious or monitoring an action that already has sufficient safeguards built in.

Finally, nations with temperate forests have committed to a process (the Montreal process) that uses agreed criteria and indicators to assess ecologically sustainable forest management. This protocol developed from the 1993 Convention of Biological Diversity held in Rio de Janeiro and was agreed to by the Commonwealth of Australia and the States in August 1998 (Anon 1998). The agreed phased implementation of indicators is outlined in Attachment 2. FORESTCHECK will contribute to indicators 3.1a, 1.2c, 3.1c and 4.1e. Some

possible indicators of ESFM in jarrah and karri forests and other southwest forest ecosystems are tabulated in Attachment 3.

When the Minister for the Environment approved the Forest Management Plan, he set a number of Ministerial Conditions that CALM had to address. Those relevant to monitoring are:

3-1 *The proponent shall manage karri and karri-marri forest in accordance with a precautionary approach. This approach requires that where there is a significant risk that a particular forest management measure could lead to an irreversible consequence, appropriate monitoring and subsequent adjustments to management within an acceptable time-frame be carried out.*

3-2 *The proponent shall manage the jarrah forest in accordance with the following general principles:...*
*(2) adaptive and flexible management practices based on research and monitoring of environmental monitoring of operations...;*

5-3 *The proponent shall monitor the effectiveness of the travel route (road) river and stream reserves for nature conservation and protection of water quality to the requirements of the Minister for the Environment.*

11-1 *The proponent shall implement the jarrah silvicultural prescription so that the monitoring of the environmental impacts on a representative range of treated sites and localities in the forest can be carried out to the requirements of the Minister for the Environment. This shall include long term monitoring which quantifies the impacts of silvicultural practices on environmental elements and values in the forest and provide bases to adjust management.*

12-3 *The proponent shall monitor, to the requirements of the Minister for the Environment, and report by 2002 on the status and effectiveness of these measures to protect nature conservation values and water quality at the time of the next review of the Forest Management Plans and Timber Strategy.*

In signing the RFA, the WA Government agreed to:

42. *Within 5 years of the date of this Agreement, Western Australia will further improve its Forest Management System and processes through the development and implementation of environmental management systems in accordance with the principles specified in Attachment 13 and the actions identified in Attachment 5 and acknowledges that its objective for native forest management under the CALM Act is system certification comparable with ISO 14000 series. The Parties note that such a system would include independent auditing of compliance with Codes of Practice and the Forest Management Plan.*

46. *Western Australia will report on the results of monitoring of sustainability indicators as part of each 5 year review and report in accordance with Clauses 36 and 37.*

47. *Comprehensive Regional Assessments, the development of criteria and indicators for sustainable forest management through the Montreal Process and the development of this Agreement have provided extensive opportunities for public participation and reporting. Parties note the range of reporting and consultative mechanisms that currently exist in Western Australia (see Attachment 4) and agree that Western Australia will further develop these by implementing the improvements specified in Attachment 4.*

51. *The Parties agree that the current Forest Management System will be enhanced by further developing appropriate mechanisms to monitor and review the sustainability of Forest management practices. To ensure that this occurs, in consultation with the Commonwealth, the State agrees to establish an appropriate set of sustainability indicators to monitor Forest changes. Any indicators established will be consistent with the Montreal Process Criteria (as amended from time to time), the current form of which is specified in Attachment 7, and will take into account the framework of regional indicators developed by the Montreal Process*

*Implementation Group. Western Australia will implement those indicators, which are practical, measurable, cost-effective and capable of being implemented at the regional level and will monitor them at an appropriate frequency determined in consultation with the Commonwealth.*

52. *Development of indicators, and collection of results for those indicators, which can be readily implemented, will be completed in time to enable reporting during the first five-yearly review of this Agreement.*

## Purpose of FORESTCHECK

FORESTCHECK is intended to serve as a framework to quantify, record, interpret and report on the status of key forest organisms, communities and processes in response to both forest management activities and natural variation. Monitoring is an essential part of systematic best practice management in order to achieve the objective of ESFM. FORESTCHECK will provide relevant information to judge whether forest biological diversity is being sustained indefinitely, part of the overall objective of the 1994 Forest Management Plan (LFC 1994).

This broad objective can be structured into more focused targets, as follows:

In each forest ecosystem (Bradshaw *et al.* 1997), our goal is to ensure that:

a) no species becomes extinct, or falls to irretrievably low levels, as a result of management activities;
b) water quality is maintained within acceptable (potable) limits;
c) species assemblages at the coupe level recover in time (before the next logging event);
d) the physical condition of the soil is protected.

These goals form the basis of more detailed monitoring objectives, involving all species of vertebrates and vascular flora (abundances), a selection of microbiota (invertebrates and macrofungi), and several practical measures of ecosystem processes relating to soil, water, vegetation growth, and foliage. Because microbiota are mostly unnamed and few species have been studied, it is necessary to focus on those groups for which some pertinent information is available. Similarly, ecosystem processes operate at many different spatial and time scales and have not yet been analysed comprehensively by scientists. Hence it is necessary to monitor those attributes that are relevant but inexpensive to measure.

Monitoring is not experimental research. Monitoring is intended to track management performance over large space and time scales in relation to stated goals, whereas experimental research is to discover the causes of observed phenomena. Monitoring serves management by demonstrating long-term trends in the performance of measured attributes. If such trends are downwards or slow to improve, management is then alerted to the need to conduct investigations, which may include experimental research.

FORESTCHECK is a simple, practical, credible and integrated system that will satisfy (over time) a number of requirements, namely Ministerial Conditions, RFA, the biological subset of Montreal Process criteria and indicators of ESFM, a more generalized retrospective study, Western Shield monitoring in forests, and validation of vertebrate surveys in forest blocks by P Christensen and G Liddelow.

Phase I of FORESTCHECK is intended to satisfy Ministerial Conditions applied to the 1994 Forest Management Plan (jarrah silvicultural systems). Phase II will involve a sophisticated retrospective analysis of historical disturbance information and assess the impact of

disturbance across many taxa and a wider range of forest ecosystems. Phase II is not considered further in this document.

FORESTCHECK deals only with monitoring. Compliance of Departmental operations with policies, prescriptions, codes of practice etc. is addressed elsewhere in CALM through Management Audit Branch.

**Proposed structure of FORESTCHECK, Phase I (jarrah silvicultural systems)**

FORESTCHECK will be based on fundamental environmental and disturbance themes:

a) Forest Ecosystems in the RFA area (Map 12 in CRA). It is expected that 4 broad jarrah forest ecosystems (north-west jarrah, north-east jarrah, southern jarrah and Blackwood jarrah) will cover most logging operations pertaining to the Ministerial Condition.

b) Logging since 1990 (9 years) under the 3 main silvicultural systems (thinning, gaps, shelterwood), of the 7 systems currently in use.

c) Forest fire history
This information, dating back to 1937, is being progressively converted from microfiche to GIS.

Therefore, a FORESTCHECK site will have attributes in relation to a forest ecosystem, a logging history, and a prescribed burning history. Sample plots will be located in various disturbance classes (shelterwood, gap, buffers not recently logged) within a FORESTCHECK site, which will be replicated.

Few existing sites for which adequate biological information is available (Water & Rivers Commission sample sites, existing growth plots, botanical sampling sites established for the RFA, Western Shield monitoring sites, experimental catchments, etc.) align with proposed FORESTCHECK sites. This reinforces the need for a better integrated system for monitoring the forests of south-west Western Australia.

The following principles will be followed:

i) Because of the spatial and temporal scale involved and the vast number of plant, invertebrate and fungal species present in forests, simplicity will be favoured over complexity e.g. ordinal data, counting only of indicator species, presence [= recorded] / absence [=not recorded]. Quantified measures of abundance will, however, be made of vertebrate species.

ii) Unlogged or lightly logged reference sites (controls) will be selected to serve to distinguish natural change from imposed change.

iii) The unit of study (a FORESTCHECK site) will be at the landscape scale of 10-100 ha, consisting of several disturbance types in close proximity.

iv) Indicator species will be selected to maximize contrasts in functional ecological traits (vital attributes), e.g., mobility (dispersal capability), home range, time to first flowering/fruiting (obligate seeders with long juvenile periods, obligate seeders dependent on canopy-stored seed), slow-growing perennials subject to mechanical destruction, *Phytophthora*-vulnerable taxa, plants acting as substrates for cryptic and other epiphytes where the epiphyte requires mature hosts, summer/autumn flowering species, fecundity, trophic position, nesting substrate, feeding substrate, degree of specialization), taxonomic position (e.g. with reference to the Five Kingdom concept of Margulis & Schwartz 1988), and status (e.g. Declared Rare Flora). A balanced array of sensitive and robust species will be selected. Refer to Attachment 3.

v) Sampling will be at the patch level (up to 10 ha), so that data can be aggregated to the landscape level.

vi) Ecosystem processes such as nett primary productivity, nutrient and water cycling, and energy transfer cannot usually be monitored directly because of insufficient knowledge or logistic impediments. These processes will thus be approximated by key habitat attributes, e.g. litter depth (for soil organic matter), stand basal area (for tree growth and salinity), turbidity in higher order streams, compaction, and foliar nutrients.

vii) Biodiversity (here treated as species richness as a necessary simplification) will be calculated for all vertebrate and plant species present, but only for selected groups of invertebrates and fungi.

viii) Some groups or topics for which knowledge is deficient, will need to be studied initially by way of special research effort, e.g. owls, bats, locally endemic invertebrates, substrate-dwelling and other freshwater invertebrates, soil carbon.

Some attributes cannot at present be sampled directly because of inaccessibility, e.g. canopy arthropods (25-30m above ground level).

**Sampling design**

The major elements of each monitoring site are as follows:

| | | |
|---|---|---|
| 1. | Forest Ecosystem | 4 types. Initial emphasis will be placed on the Jarrah Forest North West Forest Ecosystem type, as that is where most logging in the 1990s has taken place. |
| 2. | Logging disturbance | 3 timber harvesting methods, identified as % of stems retained, and 2 reference types, not logged in the 1990s [one in a road or stream reserve; the other in adjacent recently unlogged or lightly logged forest]. |
| 3. | Time since logging | Areas logged in 1990, 1995 and 2000 will provide snapshots of forest 10, 5 and 1 year after logging. |

In addition, where there is a strong topographical contrast, such as close to the Darling Scarp, a ridge/valley comparison will be included.

Thus, over time, FORESTCHECK will consist of about 36 monitoring sites, comprising 4 forest ecosystems x 3 times since logging x 3 replicates.

Because FORESTCHECK is the monitoring component of an adaptive management approach, and is not a scientific experiment, we are not attempting to align the Department's prescribed burning program with FORESTCHECK sites. Prescribed burning usually follows within 2 years of logging, and then recurs some 5-10 years later, dependent on fuel accumulation ratio, on burning days available and human resources. Records of all prescribed burning operations will be kept so that recovery of indicators following fire can be tracked. Over time the impact of fire will be able to be factored out. Phase II of FORESTCHECK will examine much more systematically the effect of various fire regimes on biodiversity.

At each FORESTCHECK site there will be a set of sample plots as shown in Table 1. It is envisaged that each of the eight (current) CALM forest districts will have 4-5 permanent monitoring sites established. An even allocation of these sites across districts is intended to spread Regional Services staff resourcing of Departmental monitoring obligations across districts.

Each segment of the mosaic will be sampled using a combination of suitable methods and time of sampling will be based on biological attributes (see Table 1).

Initially a more intensive census of vertebrates and vascular and cryptogam flora will take place.

Harvesting treatments will be assessed as level of impact (tree cover, basal area retained) in the categories gap, shelterwood etc.

Sampling frequency will need to be flexible. It is unlikely that sufficient resources will be available to re-sample monitoring sites more frequently than 2-4 years (longitudinal study). Sampling in the first year will provide the necessary short-term retrospective focus of 1-10 years since logging.

**Hypothesis testing, false positives, false negatives, and statistical power**

Hypotheses cannot logically be proven correct, as inability to invalidate a hypothesis does not necessarily prove it to be true. However, incorrect hypotheses can be demonstrated to be false. For most of the period since the rise of physical science as a discipline of rigorous inquiry, the least preferred outcome has been that of the false positive, where an untrue connexion between two factors as cause and effect has been accepted as correct (Type I error). In environmental science, however, the false negative (where a lack of an impact is wrongly accepted as correct, Type II error) potentially has irreversible consequences through the continuance of the threatening process.

In any monitoring study, it is important to consider statistical power. In simple terms, statistical power encapsulates the obvious notion that a study must be sufficiently replicated to give reasonably precise estimates of the measured parameters. In monitoring, where comparisons are often made between a 'control' and 'impact' treatment, this precision must be sufficient to detect any biologically important differences. If a variety of organisms are to be monitored, varying levels of replication may be needed for each in order to accommodate their different levels of variability.

However, determining what constitutes 'sufficient' replication prior to commencing a study is difficult. Previous studies may provide information, as will pilot studies. However, many studies have found that *a priori* power analysis is so inaccurate as to be almost worthless, leading some to argue that power analysis itself is irrelevant (Green 1994).

We recognize the value of power analysis, however, and prefer a compromise approach. In those cases where previous data are available, we will attempt to estimate requisite sample sizes. WA forest data exist for some birds (M Craig PhD thesis study at Kingston and Williams *et al.* Gray karri bird study) and invertebrates (K Strehlow PhD thesis study at Kingston). For other groups, power analysis can be conducted once sufficient data have amassed. These *a posteriori* power analyses will enable the sampling strategies to be adjusted to achieve adequate power.

The final important aspect of power analysis is that it enforces an explicit consideration of effect sizes and specification of null and alternate hypotheses. In monitoring, these hypotheses are:

$H_o$: The mean for the disturbed site is equal to the mean of the reference site.
$H_a$: The mean for the disturbed site is greater than, less than, or equal to the mean of the reference site.

In $H_a$, the one-sided alternatives may be appropriate for some organisms where the form of the response to disturbance is known. The effect sizes are the degree to which differences between the treated and reference sites are deemed of biological importance. Thus, for one species the criterion may be that its abundance be >90% of that at the reference site. For another, it may be that it is present at the same proportion (within 5%) of disturbed, as at reference, sites.

**Sampling methodology**

The major constraint in designing sampling protocols is the 10 ha size of forest cut to gaps. If plots or grids are too large, the buffer area will be compromised and any effects due to treatment will thus be confounded.

At each FORESTCHECK site, the following is proposed (a summary is presented in Table 1). Treatments are defined as forest that is either shelterwood cut, thinned, gap cut, uncut buffers/reserves or unlogged controls. Each FORESTCHECK site will be assessed at 2-5 yearly intervals, depending on availability of resources and time since disturbance, with more regular assessments soon after disturbance. Outputs and estimates of the time taken to complete fieldwork at an FORESTCHECK site are also provided.

*Plants and Cryptogams*

Four 30 m x 30 m plots will be marked out in each treatment. In spring the abundance of each understorey plant species (including jarrah/marri ground coppice) within the plots will be ranked as follows: 1 (plant rare, insignificant cover found); 2 (few plants, <1% cover), 3 (common, 30% cover), 4 (abundant, plants throughout plot), 5 (totally dominates plot). Voucher specimens will be taken. The cover and height of the understorey stratum (<2 m) will be estimated using the 'drop plate' technique. Tree basal area will be determined by a basal area sweep from the middle of the plot using a wedge prism.

Crytogams will be assessed as for vascular flora, except that species cover will be estimated.

Outputs: Species richness, composition and abundance (also classified by regeneration mode), invasion by exotic plant species understorey structure and cover, overstorey composition and density.

Estimated effort: 2 people for 16 hrs.

*Invertebrates*

Within each treatment, an area of *c.* 1 ha will be searched before 1100 hr and after 1500 hr (so as to counter diurnal effects) by two people for 1.5 hrs in spring and in autumn. Each indicator species is recorded as: 0 (not found); 1 (few found); 2 (commonly found). Six microhabitats (open ground, leaf litter, lower boles of trees, moss swards, ashbeds, on and underneath coarse woody debris) will each be searched for 15 minutes.

Ten pitfall traps (92 mm wide x 108 mm deep) will be installed 10 m apart along a 100 m transect, set diagonally across the 1 ha plot, and left in operation for 24 hrs (1000-1000 hr).

Because ants have been comparatively well studied in jarrah forests, one specimen of each different ant species will be collected from ant nests or trails. A reference collection will be established.

Outputs: Ranked abundance of indicator species.

Estimated effort: 2 people for 9 hrs (spread over 3 days).

*Macrofungi*

Fungi occur on trees, dead wood and on the ground and have specific microclimate requirements. Transects are the most appropriate sampling method and will take in the wide variation of substrate and microclimate present in a forest.

The only practical method of monitoring forest fungi is by measuring fruitbodies. This presents several problems:

(i) fungal fruiting is weather dependent, and with a low monitoring frequency temporal variation in the species recorded can occur.

(ii) the presence of fruitbodies of a particular species of fungi indicates the presence of the fungus, however, the absence of fruitbodies does not indicate absence of the fungus (it may be present in the soil/wood substrate but has not fruited).

It is not meaningful to measure abundances (numbers) of fruitbodies of a particular species, as one mycelium in a substrate may produce either multiple or single fruitbodies and abundance will vary from year to year. A better measure is the presence or absence of fruitbodies of a particular species.

Fungi play three major and very important roles in forests, acting as (i) nutrient suppliers to plants (in the form of mycorrhizas), (ii) nutrient recyclers (decomposers) and (iii) pathogens.

Wood and leaf litter fungi are assessed on a 4 m wide transect (100 m in length) in late autumn/early winter and in spring. Macrofungal identification will be at the level of genus or life-mode type (e.g. saprophytic on wood, saprophytic on leaf litter, saprophytic on twigs, fungi fruiting on soil). Each indicator is recorded as : 0 (not found); 1 (few found); 2 (commonly found).

A method of monitoring change is to measure the change in ratio of Mycorrhizal, Saprotrophic and Pathogenic fungi. Knowledge on certain species of fungi in all these groups is available. Monitoring the presence and absence of these species over a long time frame will indicate what ratio of M:S:P is present on the monitoring sites. Although the M:S:P: ratio cannot be interpreted as yet, in time it may be possible to determine which M:S:P ratio is indicative of a healthy forest (control), and how or if management treatments affect this ratio.

Outputs: Ranked abundance of indicator species.

Estimated effort: 2 people for 6 hrs

*Birds*

A study area of 1 ha (100 m x 100 m) will be established within each treatment, based on the sampling design used successfully by PhD student M Craig in the Kingston study. In each census (of 20 min), all birds that land in the study area are counted, with no distinction between whether the bird was detected by sight or sound. Birds flying over or through the study are recorded only as a species record. Where feasible, individual birds are recorded as male, female, adult or juvenile.

Each study area is censused five times during spring, with each census at least seven days apart. Censuses take place from 5 minutes before sunrise to 3 hours after sunrise in fine still weather. Previous experience indicates that five study plots can be censused in 3 hours.

Outputs: Species composition, richness and abundance.

Estimated effort: 1 person x 5 plots/day x 5 days, totalling c. 9 hrs.

*Mammals, Reptiles and Amphibians*

Within each treatment, a trapping grid will be established to monitor medium sized mammals and small vertebrates (small mammals, frogs and reptiles). Each grid will consist of a core area of 80 m x 80 m in which a 3 x 5 grid of pitfall traps (20 L buckets; 25cm wide x 40 cm deep) with a 7m long flywire fence, will be established. Superimposed on this grid will be 3 x 5 grid of wire cage traps on a 40 m spacing to capture medium-sized mammals. Mammals will be trapped in autumn, outside their breeding season and not in winter or summer when weather can stress trapped animals. Pitfall traps will be operated in late spring/summer and in autumn for reptiles and frogs. Species, weight, sex and breeding status will be determined for mammals captured, which will be individually marked, and species only, for frogs and reptiles. Each trap session will be over 3 nights.

Outputs: Species composition and richness, capture rates (abundance).

Estimated effort: 2 people x 5 grids (setting up 1 day; 6 hrs per morning x 3 mornings), totalling 26 hours.

Large vertebrate species have home ranges exceeding the size of the study area. Grey kangaroo, Brush wallaby and Emu will be counted on a 40 km long road transect from 2 hours before sunset to 15 minutes after sunset. A 10 km road transect for 2 hours at night will serve to count possums, other nocturnal arboreal mammals, and nocturnal birds by spotlight.

The abundance of foxes and cats is assessed using ten 1 m x 1 m x 7cm deep sand pads spaced 500 m apart along a track. A lure of 50-60g of meat is buried in the centre of each pad, and the pad is brushed clean each day. Sand pads should also record Chuditch tracks.

Outputs: Species and measure of abundance.

Estimated effort: 2 people, totalling 4 hours.

*Ecosystem Processes*

Litter depth, basal area, and soil composition will be measured at 20 randomly related points within the 1 ha bird study area. Foliage samples will be collected from five of these points for subsequent determination of N, P and K levels. Additional growth plots of tree species may also need installing, dependent on how adequate the existing inventory system is.

Outputs: Litter depth, basal area, soil compaction.

Estimated effort: 1 person x 10 hours.

## Responsibility for data collection

Because FORESTCHECK is integral, not incidental, to ecologically sustainable forest management, it is necessary that much of the field component has the active participation of Regional Services staff. Each forest region/district has staff currently involved in nature conservation and forest management activities. It is proposed that much of this effort be consolidated and rationalized within FORESTCHECK. This single, integrated system is designed to service many requirements which are currently being serviced often by *ad hoc* and parallel systems. In addition to rationalizing nature conservation and forest management activities at the District level, thereby enabling District staff to monitor the FORESTCHECK sites, two new positions (Co-ordinator, Technical Support) are essential to initiating plot installation, ensuring standardization in methodology, training and supervision of district staff and database management. There will be an ongoing need for research scientists to provide advice, training, and to assist with the interpretation of outputs.

## Data management

Standardized corporate databases will be set up prior to fieldwork. These will determine the recording sheet for each taxon/attribute. Once data are collected, they will require processing, management, maintenance, integration and distribution. These processes are critical to the success of FORESTCHECK. The Co-ordinator and Technical Support officer will be responsible for vouchering of specimens and the co-ordination, analysis, interpretation and initial reporting of the data collected. Details of reporting procedures need to be developed in consultation with the Conservation Commission and Director of Sustainable Forest Management in the new Department of Conservation.

Data entry will take place in the District/Region in which data are collected, and a District/Regional Officer will be appointed as data custodian.

## Public consultation and community involvement

A workshop involving CALM personnel was held in April 1999 (Attachment 4) to discuss the framework of a forest monitoring system. A CALM Implementation Group was then established (Attachment 5). The role of this group has been to guide the development of a monitoring protocol (FORESTCHECK). The resulting draft concept plan served as the basis of an external workshop held in October 1999. This was attended by 22 scientists not employed by CALM (Attachment 6). They were asked to address several issues, particularly to consider the strengths and weaknesses of FORESTCHECK, to suggest improvements to sampling design and methodology, and to provide advice on the interpretation and presentation of monitoring data. A second workshop was convened in March 2000 to address monitoring protocols and interpretation of outputs, issues that were not resolved at the first workshop. Twenty-six invitees participated in the workshop (Attachment 7). These suggestions have been used to produce this revised version of the concept plan. A summary of advice not adopted has been sent to all participants in these workshops. This summary is at Attachment 8.

It is proposed that occasional field days be held periodically in each CALM District. Interested members of the public (e.g. university students) can then participate in data collection; this may also lead to a corps of volunteers willing to assist regularly in the collection of data. This will increase the visibility of FORESTCHECK with the public. In addition, it is intended that FORESTCHECK should feature on CALM's NatureBase site (http://www.calm.wa.gov.au).

## Interpreting the results

FORESTCHECK concentrates on only some aspects of ESFM and as such can not be expected by itself to guide changes to forest management consistent with ESFM. In addition, the relative importance of specific forest values depends on community expectations that vary. Hence, what constitutes sustainable forest management will vary depending on the nature of the forest and community expectations.

Nevertheless a key challenge is to interpret change in measured variables after imposed disturbance and to decide when the trajectory of recovery during a particular period warrants consideration of change to management practices. FORESTCHECK will provide information relevant to determining recovery periods, recovery patterns and patterns in variation through time. For invertebrates and fungi, knowledge of recovery of biodiversity is minimal.

The recolonization by birds of the regenerating forest on a clearfelled karri coupe in Gray block (illustrated in Fig. 1) is provided as a real example of the type of data that will be collected by FORESTCHECK. These data show that the avifauna is "on track" in terms of the recovery trajectory. In contrast, some bird species have not recovered after 14 years (the latest 1998 information) - does this mean that the manager should adopt a worst case scenario and immediately change policy? Karri forest management is based on a rotation of 100 years, so it could be argued that some time before 100 years is the appropriate perspective.

Three broad types of output are envisaged. Trajectory graphs similar to those in Fig. 2, with standard errors of the means calculated as data accrue, will show the extent and rate that biodiversity, indicator species, and other attributes return to levels comparable to reference sites. Calculation of 95% confidence intervals will permit valid statistical comparisons. Where there are regular monotonic trajectories it may be practical to fit equations (as in Fig. 1). The second output will be ordination analysis of assemblage data (species composition), using non-metrical dimensional scaling (based on abundance data) or similarity coefficients (based on presence/absence of species). For a Western Australian example, see Armstrong and Nichols (2000). The third output is a profile diagram, showing the proportion of treatment sites at which species have been recorded. When the species are sorted in order of their frequency of occurrence in reference sites, it is straightforward to determine which species have recovered in treated sites. For an Australian example, see Alford and Richards (1999).

### Management of FORESTCHECK

There may be merit in seeking external membership on this group.

### Outcomes from FORESTCHECK

In addition to making a significant contribution to forest science and to ecologically sustainable forest management in Western Australia, FORESTCHECK will provide a framework for meaningful public participation in forest management and will deliver relevant information to satisfy the following obligations:

| | |
|---|---|
| Ministerial Condition 5.3 (part): | Turbidity, salinity, freshwater invertebrate indicators. |
| Ministerial Condition 11.1: | Vertebrate, invertebrates, plants, fungi indicators, litter depth, soil organic matter, soil bulk density. |
| Ministerial Condition 12.3: | Vertebrate, invertebrates, plants, fungi indicators, litter depth, soil organic matter, soil bulk density. |

| | |
|---|---|
| RFA 42. | Vertebrate, invertebrates, plants, fungi indicators, litter depth, soil organic matter, soil bulk density. |
| RFA 46. | Vertebrate, invertebrates, plants, fungi indicators, litter depth, soil organic matter, soil bulk density. |
| RFA 47. | Consultative mechanisms and public reporting. |
| RFA 51. | Montreal process criteria/indicators. |
| RFA 52 | Montreal process criteria/indicators. |

**Time line**

| | |
|---|---|
| March 99 | Science Management Council endorsement of draft Integrated Forest Monitoring System concept plan |
| April 99 | CALM workshop of concept plan |
| May 99 | Present revised concept plan for approval by Corporate Executive |
| Aug 99 | First meeting of Implementation Group |
| Oct 99 | Hold workshop with external experts |
| Nov 99 | Revise document for further scientific scrutiny |
| Mar 00 | Hold workshop with external experts to finalize protocol |
| May 00 | Present FORESTCHECK to Corporate Executive for approval |
| Sep 00 | Commence installation of FORESTCHECK sites |
| | Commence training of District staff |
| ?Dec 03 | Report on Ministerial Conditions |

**References**


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Table 1: A summary of the proposed sampling regime at an FORESTCHECK site. A Phase 1 FORESTCHECK site is a combination of a jarrah forest ecosystem type and a logging history. Each site will be assessed at 2-5 yr intervals. The 'Field Effort' column is an estimate of time to complete a field assessment.

| **Site attribute** | **Gap** | **Shelterwood** | **Buffer/Reserve** | **Control** | **Field Effort (person days (PD))** |
|---|---|---|---|---|---|
| Plants and Cryptogams | Four 30m x 30m plots | Four 30m x 30m plots | Two riparian, Two upland 30m x 30m plots | Two riparian, Two upland 30m x 30m plots | 4 |
| Invertebrates | 1 ha x 1.5 hr search | 1 ha x 1.5 hr search | 1 ha x 1.5 hr search riparian and upland | 1 ha x 1.5 hr search riparian and upland | 3 |
| Macrofungi | 4m x 100m transect | 4m x 100m transect | 4m x 100m transect riparian and upland | 4m x 100m transect riparian and upland | 2 |
| Birds | 1 ha census for 30 mins. | 1 ha census for 30 mins | 1 ha census for 30 mins, riparian and upland | 1 ha census for 30 mins, riparian and upland | 1 |
| Mammals/ Herps & spotlighting | 160m x 160 m trap grid x 3 nights | 160m x 160 m trap grid x 3 nights | 160m x 160 m trap grid x 3 nights: riparian and upland | 160m x 160 m trap grid x 3 nights: riparian and upland | 4 |
| Ecosystem processes | 1 ha plot (30 samples) 2 hr | 1 ha plot (30 samples) 2 hr | 1 ha plot (30 samples) 2 hr | 1 ha plot (30 samples) 2 hr | 2 |
| | | | | **TOTAL** | **16 PDs per FORESTCHECK site, or 30-35 PDs/ District/yr if sites assessed biennially** |

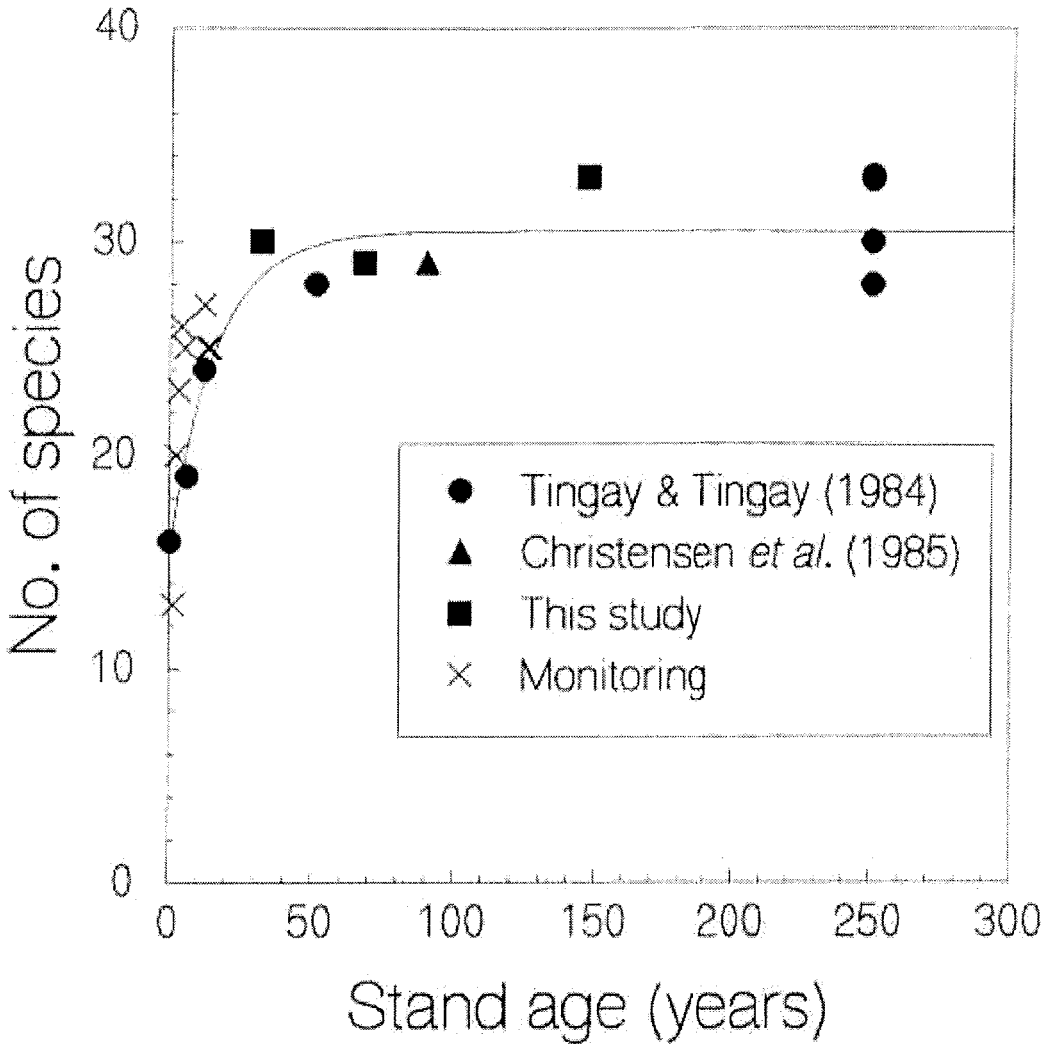
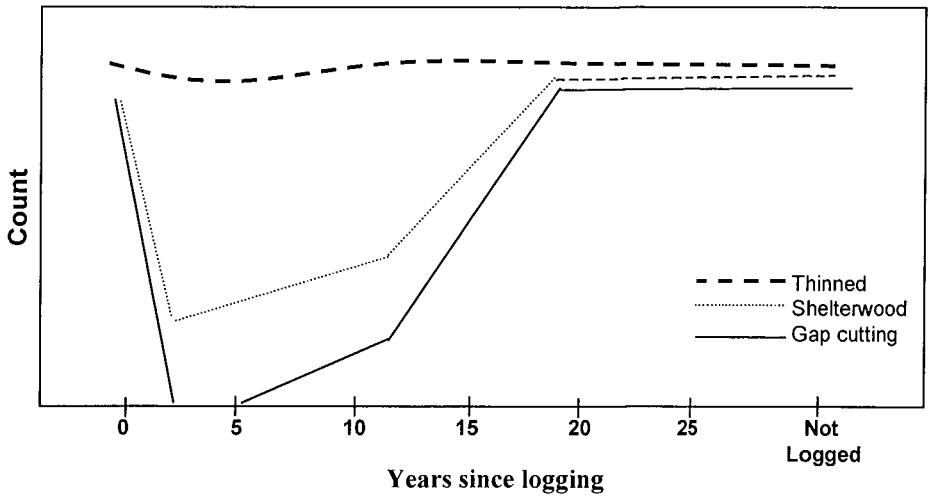

40
30
20
10
0
No. of species
0
50
100
150
200
250
300
Stand age (years)
Tingay & Tingay (1984)
Christensen et al. (1985)
This study
Monitoring

Figure 1

(a)


Count
Thinned
Shelterwood
Gap cutting
0
5
10
15
20
25
Not Logged
Years since logging

(b)

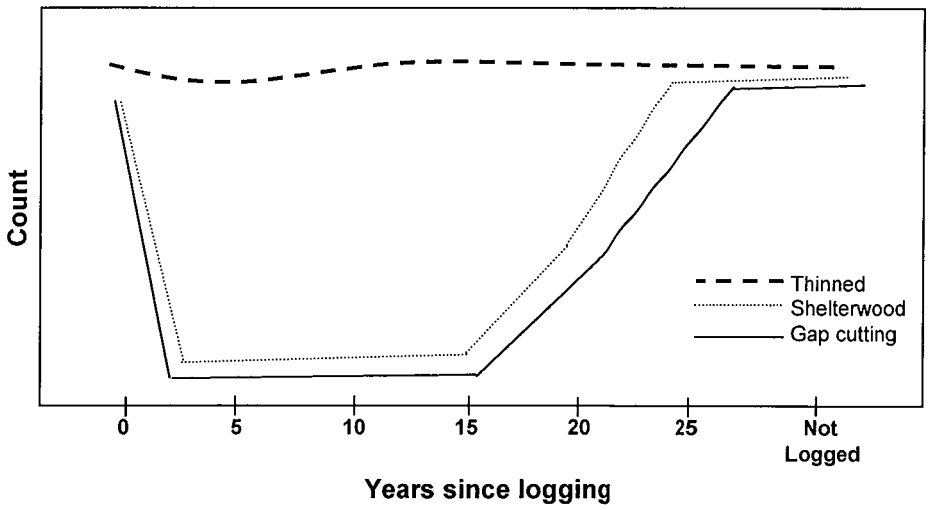

Count
Thinned
Shelterwood
Gap cutting
0
5
10
15
20
25
Not Logged
Years since logging

**Figure 2**

**DRAFT**

ATTACHMENT 3

# EXAMPLES OF POSSIBLE CRITERIA / INDICATORS OF ECOLOGICALLY SUSTAINABLE FOREST MANAGEMENT

| Criterion/Indicator of ESFM | FOREST ECOSYSTEM (refer to map 12 of the Comprehensive Regional Assessment Volume 2) | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jarrah Forest - North West | Jarrah Forest - South | Jarrah Forest- Blackwood Plateau | Jarrah Forest - North East | Shrub, Herb & Sedgelands | Karri - Main Belt | Wandoo Forest | Jarrah Forest - Sandy Basins | Peppermint & Coastal Heath | Jarrah Forest - Open Woodland | Wandoo - Open Woodland | Jarrah Forest - Mt Lindesay | Jarrah Forest - Unicup | Rocky Outcrops | Karri/ Yellow Tingle | Jarrah Forest - Leeuwin Ridge | Jarrah Forest - Yellow Tingle | Swamps | Karri/Red Tingle | Karri - West Coast | Darling Scarp Vegetation | Bullich & Yate Woodland | Jarrah Forest - Rates Tingle | Karri - South Coast | Karri/Rates Tingle | Jarrah Forest - Red Tingle |
| Area (ha) | 448,987 | 419,860 | 268,789 | 266,177 | 260,759 | 153,905 | 105,193 | 65,753 | 60,379 | 56,661 | 51,128 | 30,291 | 17,366 | 12,444 | 11,841 | 10,315 | 8,450 | 6,654 | 5,105 | 4,774 | 3,470 | 2,179 | 1,069 | 729 | 736 | 229 |
| **LARGE HOLLOWS IN STANDING TREES** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Forest red-tail black cockatoo | • | • | • | • | | | | • | | • | | • | • | | | • | • | | | | | | • | | | • |
| Coomal (Brushtail possum) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ngwayir (Western ringtail-possum) | • | • | • | | | • | | • | • | • | | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Baudin's Cockatoo | • | • | • | | | • | | | | | | | | | • | | | | • | • | | | | • | • | |
| Carnaby's Cockatoo | | | | | | | • | | | | • | | | | | | | | | | | | | | | |
| **HOLLOWS IN STANDING TREES** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Common brush-tailed phascogale | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| **HOLLOWS ON GROUND** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Chuditch | • | • | • | • | | | • | • | • | • | • | • | • | | | • | • | | | | | • | • | | | • |
| Numbat | • | • | • | • | | | • | • | • | • | • | • | • | | | • | • | | | | | • | • | | | • |
| **OVERSTOREY FEEDER** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Spotted pardalote | • | • | • | • | | • | • | • | | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Striated pardalote | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Western white-naped honeyeater | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| **OBLIGATE RIPARIAN SPECIES** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Red-winged fairy-wren | • | • | • | | | • | | | | | | • | • | | • | • | • | | • | • | | | • | • | • | • |
| Splendid fairy-wren | • | • | • | • | | | | | | • | | | • | | | • | | | | | | | | | | |
| Whitebrowed scrubwren | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Red-eared firetail | • | • | • | | | • | | | | | | • | • | | • | • | • | | • | • | | | • | • | • | • |
| **SOIL PROPERTIES** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bulk density | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| Organic C | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| **BATS** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **FROGS** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **REPTILES** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **SLOW TO RECOLONIZE CLEARFELLED KARRI** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rufous tree creeper | | | | | | • | | | | | | | | | • | | | | • | • | | | | • | • | |
| White-breasted robin | | | | | | • | | | | | | | | | • | | | | • | • | | | | • | • | |
| White-browed babbler | | | | | | • | | | | | | | | | • | | | | • | • | | | | • | • | |
| Golden whistler | | | | | | • | | | | | | | | | • | | | | • | • | | | | • | • | |
| Western gerygone | | | | | | • | | | | | | | | | • | | | | • | • | | | | • | • | |
| Black-faced cuckoo-shrike | | | | | | • | | | | | | | | | • | | | | • | • | | | | • | • | |
| **INTRODUCED SPECIES OR NATIVE SPECIES NOT ORIGINALLY PRESENT** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Red fox | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| House mouse | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Black-shouldered kite | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Singing honeyeater | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| White-fronted chat | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Red-capped robin | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Willie wagtail | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Magpie lark | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| White-winged triller | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Grey butcher bird | • | • | • | • | | • | • | • | • | • | • | • | • | | • | • | • | | • | • | | • | • | • | • | • |
| Richard's pipit | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |

**DRAFT**

| Criterion/Indicator of ESFM | FOREST ECOSYSTEM (refer to map 12 of the Comprehensive Regional Assessment Volume 2) | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jarrah Forest - North West | Jarrah Forest - South | Jarrah Forest- Blackwood Plateau | Jarrah Forest - North East | Shrub, Herb & Sedgelands | Karri - Main Belt | Wandoo Forest | Jarrah Forest - Sandy Basins | Peppermint & Coastal Heath | Jarrah Forest - Open Woodland | Wandoo - Open Woodland | Jarrah Forest - Mt Lindesay | Jarrah Forest - Unicup | Rocky Outcrops | Karri/ Yellow Tingle | Jarrah Forest - Leeuwin Ridge | Jarrah Forest - Yellow Tingle | Swamps | Karri/Red Tingle | Karri - West Coast | Darling Scarp Vegetation | Bullich & Yate Woodland | Jarrah Forest - Rates Tingle | Karri - South Coast | Karri/Rates Tingle | Jarrah Forest - Red Tingle |
| Area (ha) | 448,987 | 419,860 | 268,789 | 266,177 | 260,759 | 153,905 | 105,193 | 65,753 | 60,379 | 56,661 | 51,128 | 30,291 | 17,366 | 12,444 | 11,841 | 10,315 | 8,450 | 6,654 | 5,105 | 4,774 | 3,470 | 2,179 | 1,069 | 729 | 736 | 229 |
| **PLANT SPECIES (S = seed regenerator; R = resprouter; () = first flower 3 or more years after fire)** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Acacia pentadenia* S (4) | | • | | | | • | | | | • | | • | | | • | | | | • | • | | | | • | • | |
| *Acidonia microcarpa* S | | | | | • | | | | | | | | | | | | | • | | | | | | | | |
| *Actinostrobus pyramidalis* S (5-10) | | • | | • | • | | • | | | | | | • | | | | | • | | | | | | | | |
| *Agonis hypericifolia* R (3) | | • | | | • | | • | | • | | | • | • | | | | | | | | | | | | | |
| *Banksia attenuata* R | • | | • | • | • | | • | • | • | | | | | | | | | | | | | | | | | |
| *Banksia littoralis* S (3) | • | • | • | • | • | | | • | • | | | • | • | | | • | | • | | | | | | | | |
| *Banksia quercifolia* S (3) | | | | | • | | | | | | | | | | | | | | | | | | | | | |
| *Banksia seminuda* S (6) | • | • | | | • | • | | | • | | | | | | | | | | | | | | | | | |
| *Banksia verticillata* R | | | | | | | | | • | | | | | • | | | | | | | | | | | | |
| *Bossiaea aquifolium* S | • | • | • | | | • | | • | | | | | | | | • | | | | | | | | | | |
| *Bossiaea ornata* R (3) | • | • | • | • | | | • | • | | | | • | | | | • | | | • | | | | | | | |
| *Bossiaea linophylla* (3) | • | • | • | • | | • | | • | • | | | • | • | | | • | | | | • | | | | | | |
| *Conospermum capitatum* R (3) | • | • | • | • | | | | | • | | | • | • | | | • | | | | | | | | | | |
| *Dasypogon hookeri* R | | • | • | | | | | | | | | | | | | • | | | | | | | | | | |
| *Dryandra bipinnatifida* R (3) | • | • | • | • | | | • | • | | | | | • | | | | | | | | | | | | | |
| *Dryandra lindleyana* R (4) | • | • | • | | | | • | • | | | | | | | | • | | | | | | | | | | |
| *Dryandra serra* R | | • | | | | | | | | | | • | | | | | | | | | | | | | | |
| *Dryandra sessilis* S (3) | • | • | • | • | | | • | • | • | | | | | | | • | | | | | | | | | | |
| *Dryandra squarrosa* | | | • | • | | | • | • | | | | | | | | • | | | | | | | | | | |
| *Eucalyptus megarcarpa* R/S (4) | • | • | • | | | • | | | • | | | • | • | • | • | • | | • | • | • | | • | | | | |
| *Gastrolobium bilobum* S (3) | • | • | | • | | | • | | • | | | | • | | | • | | | | | | | | | | |
| *Hakea lasianthoides* S | • | • | • | | | • | • | | | | | | | | • | • | • | | • | • | | | | | | |
| *Hakea falcata* | | • | • | | • | | • | | | | | • | | | | | | | | | | | | | | |
| *Hakea oleifolia* S | | • | • | | | | • | | • | | | • | • | | | • | | | | | | | | | | |
| *Hakea trifurcata* | • | • | | • | | | • | | | | | • | • | | | | | | | | | | | | | |
| *Hakea undulata* (4) | • | • | | • | | | • | • | | | | • | • | | | | | | | | | | | | | |
| *Hovea trisperma* S (4) | • | • | • | • | | | • | • | • | | • | • | • | | | • | | | | | | | | | | |
| *Kingia australis* R | • | • | • | | • | • | | • | | | | • | | | • | • | • | | | | | | | | | • |
| *Lambertia orbifolia* | | | • | | • | | | | | | | | | | | | | | | | | | | | | |
| *Lambertia rariflora* S (6) | | • | • | | | | | | | | | | | | | | | | | | | | | | • | |
| *Lepidosperma squamatum* R (4) | • | • | • | • | • | • | | • | • | • | | • | • | | | • | | | • | • | | | | | | |
| *Lomandra integra* R (4) | • | • | • | | • | • | • | | • | | • | • | | | • | • | • | | • | | | | | | | |
| *Macrozamia riedei* R/S | • | • | • | • | • | • | • | • | | | | • | • | • | • | • | • | | | | | | | | | |
| *Melaleuca incana* | • | • | • | • | • | | • | • | • | | • | | | | | • | | | | | | | | | | |
| *Melaleuca viminea* S (6) | • | • | | • | • | | • | • | • | | | | • | | | • | | | | | | | | | | |
| *Persoonia elliptica* R | • | • | • | • | | | | • | • | | | • | | | | • | | | | | | | | | | |
| *Poa homomalla* R | • | • | | | | • | | | | | | | | | | • | | | | | | | | | | |
| *Schaerolobium medium* R/S | • | • | • | • | • | • | • | • | • | | | • | • | • | • | • | • | | • | | | | | | | |
| *Tetratheca setigera* S | • | • | • | • | • | | | | • | | | • | • | | | • | • | | • | | | | • | | • | |
| *Trymalium floribundum* S (3) | • | • | | • | | • | • | • | • | | | | | | • | • | | | • | • | | | | • | | |
| *Trymalium venustum* | | • | | | | | | | | | | • | | | | | | | | | | | | | | |
| *Xanthorrhoea drummondii* R | | | | ? | | | • | | | | | | | | | | | | | | | | | | | |
| *Xylomelum occidentale* R | • | • | • | | | | | • | • | | | | | | | • | | | | | | | | | | |
| *Xanthorrhoea preissii* R/S | • | • | • | • | | • | • | • | • | | | • | • | • | • | • | • | | | | | | | | | |
| **LICHEN** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **MOSS** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **MYCORRHIZAL FUNGI** | | | | | | | | | | | | | | | | | | | | | | | | | | |

**DRAFT**

| Criterion/Indicator of ESFM | FOREST ECOSYSTEM (refer to map 12 of the Comprehensive Regional Assessment Volume 2) | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jarrah Forest - North West | Jarrah Forest - South | Jarrah Forest- Blackwood Plateau | Jarrah Forest - North East | Shrub, Herb & Sedgelands | Karri - Main Belt | Wandoo Forest | Jarrah Forest - Sandy Basins | Peppermint & Coastal Heath | Jarrah Forest - Open Woodland | Wandoo - Open Woodland | Jarrah Forest - Mt Lindesay | Jarrah Forest - Unicup | Rocky Outcrops | Karri/ Yellow Tingle | Jarrah Forest - Leeuwin Ridge | Jarrah Forest - Yellow Tingle | Swamps | Karri/Red Tingle | Karri - West Coast | Darling Scarp Vegetation | Bullich & Yate Woodland | Jarrah Forest - Rates Tingle | Karri - South Coast | Karri/Rates Tingle | Jarrah Forest - Red Tingle |
| Area (ha) | 448,987 | 419,860 | 268,789 | 266,177 | 260,759 | 153,905 | 105,193 | 65,753 | 60,379 | 56,661 | 51,128 | 30,291 | 17,366 | 12,444 | 11,841 | 10,315 | 8,450 | 6,654 | 5,105 | 4,774 | 3,470 | 2,179 | 1,069 | 729 | 736 | 229 |
| *Pisolithus tinctorus* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Paxillus muelleri* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Peziza* spp. | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Russula clelandii* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Amanita xanthocephala* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Mesophellia* spp. | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **SAPROTROPHIC FUNGI** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Gymnopilus austrosapineus* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Coltricia oblectans* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Boletellus obscurecoccineus* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **PATHOGENIC FUNGI** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Armillaria luteobubalina* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **AQUATIC INVERTEBRATES** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TERRESTRIAL INVERTEBRATES** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Millipedes** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cynotelopus notabilis* (litter) | | | | | | • | | | | | | | | | | | | | | | | | | • | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Spiders** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Storena tetracha* (litter) | | | | | | • | | | | | | | | | | | | | | | | | | • | | |
| *Dardurus* sp.n. (litter) | | | | | | • | | | | | | | | | | | | | | | | | | • | | |
| *Baiami* spp. (log) | | | | | | • | | | | | | | | | | | | | | | | | | | | |
| *Badumna microps* (bark) | • | • | • | | | • | | • | | | | • | | | • | • | • | | | | | | | • | | |
| *Moggridgea tingle* (bark) | | | | | | | | | | | | | | | • | | | | • | | | | | | | • |
| *Chenistonia villosa* (bark + soil) | | | | | | • | | | | | | | | | | | | | | | | | | | | |
| *Diaea socialis* (foliage) | | | | | | • | | | | | | | | | • | | | | • | | | | | • | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Sawfly** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tenthredinidae (pupae) (foliage) | • | • | • | • | • | • | • | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Ants** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Myrmecia* (predator) | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| *Iridomyrmex greensladei* (canopy breakdown) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Iridomyrmex anceps* JDM 351 (undisturbed forest) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cardiocondyla nuda* (gross disturbance) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Monomorum* sp. (post-disturbance) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Papyrus nitidus* (undisturbed forest) | | | | | | | | | | | | | | | | | | | | | | | | | | |
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# MILESTONES IN RESEARCH AND MONITORING IN THE SOUTHWEST FORESTS OF WESTERN AUSTRALIA

| | |
|---|---|
| 1842 | First vertebrate specimens collected for scientific study |
| 1890 | First publication on the forest avifauna |
| 1916 | First growth plots for trees established |
| 1936 | First paper published on predictability of fire behaviour from weather variables |
| 1955 | First fire impact study of soil/litter fauna published |
| 1961 | First thesis on jarrah and karri silviculture |
| 1964 | First thesis on forest floor dynamics and soil properties in jarrah forest |
| 1969 | First comprehensive experimental studies of karri silviculture commenced |
| 1970 | Commencement of first integrated biological survey |
| 1972 | Paper establishing the cause of dieback disease published |
| 1972 | Commencement of long term studies of forest mammals - Perup forest |
| 1972 | First thesis on forest fire behaviour and fire danger rating system |
| 1972 | Commencement of long term study of fire effects in southern forests |
| 1975 | Comprehensive review of fire impact studies on flora and vertebrate fauna published |
| 1975 | Site-vegetation types in northern jarrah forest described |
| 1980 | Hypothesis linking decline of native mammal species to fox predation published |
| 1982 | Commencement of long-term study of impact of clearfelling on the karri forest avifauna. |
| 1985 | First logging impact study of soil/litter fauna published |
| 1985 | First logging impact study of avifauna published |
| 1986 | Comprehensive synthesis of knowledge about the ecology of jarrah published |
| 1988 | Site-vegetation types in southern jarrah forest described |
| 1989 | Comprehensive review of knowledge about dieback disease published |
| 1989 | Critical review of fire impact studies published |
| 1989 | Publication of multi-authored book on the ecology and management of the northern jarrah forest |
| 1990 | Publication of book on threatened flora |
| 1991 | Jarrah forest growth inventory completed |
| 1992 | Publication of book on the ecology and management of karri forest |
| 1992 | Initiation of a four-year study of the impact of spring and autumn planned fire on surface-active species of litter invertebrates |
| 1993 | Initiation of multidisciplinary and integrated study of logging and fire impacts in jarrah forest ("Kingston project") |
| 1994 | Integrated study of the occurrence of hollows in standing trees commenced |
| 1995 | Monitoring commenced of the occurrence of a bio-indicator of large hollows in standing trees (Forest red-tailed black cockatoo) |
| 1995 | Comprehensive synthesis of knowledge about the silviculture of karri published |
| 1998 | Comprehensive regional assessment published, containing a wealth of new information about forest ecosystems, vegetation complexes, floristic diversity etc. |
| 1999 | Planning for an Integrated Forest Monitoring System commenced |
| 1999 | Comprehensive synthesis of knowledge about forest avifauna published |

## Table 1: Agreed phased implementation of indicators

| Category A—Largely implementable now | Category B—Require some development | Category C—Require longer-term R&D |
|---|---|---|
| **1.1.a** Extent of area by forest type and tenure. (Amended to include 1.1.c) | **1.1.e** Fragmentation of forest types. | **1.2.c** Population levels of representative species from diverse habitats monitored across their range. |
| **1.1.b** Area of forest type by growth stage distribution by tenure. (Amended to include 1.1.d) | **5.1.a** Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages. | **1.3.a** Amount of genetic variation within and between populations of representative forest dwelling species. |
| **1.2.a** A list of forest dwelling species. | **6.1.a** Value and volume of wood and wood products production, including value added through downstream processing. | **3.1.a** Area and per cent of forest affected by processes or agents that may change ecosystem health and vitality. |
| **1.2.b** The status (threatened, rare, vulnerable, endangered, or extinct) of forest dwelling species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment. | **6.3.a** Value of investment, including investment in forest growing, forest health and management, planted forests, wood processing, recreation and tourism. | **3.1.c** Area and percentage of forest land with diminished or improved biological, physical and chemical components indicative of changes in fundamental ecological processes. |
| **2.1.a** Area of forest land and net area of forest land available for timber production. | **6.4.a(i)** (priority areas) Area and per cent of forest land in defined tenures, management regimes and zonings which are formally managed in a manner which protect Indigenous peoples' cultural, social, religious and spiritual values, including non-consumptive appreciation of country. | **4.1.c** Per cent of stream kilometres in forested catchments in which stream flow and timing has significantly deviated from the historic range of variation. |
| **2.1.d** Annual removal of wood products compared to the sustainable volume. | **6.4.a(ii)** Proportion of places of non-Indigenous cultural values in forests formally managed to protect these values. | **4.1.d** Area and per cent of forest land with significantly diminished soil organic matter and/or changes in other soil chemical properties. |
| **2.1.f** Area and per cent of plantation established meeting effective stocking one year after planting. | **6.5.a** Direct and indirect employment in the forest sector and forest sector employment as a proportion of total employment. (Indirect) | **4.1.d** (Interim) The total quantity of organic carbon in the forest floor (< 25 mm diameter components) and the surface 30 cm of soil. |
| **2.1.g** Area and per cent of harvested area of native forest effectively regenerated. | **6.6.a** Extent to which the management framework maintains and enhances Indigenous values including customary, traditional and native title use by Indigenous peoples and for Indigenous participation in forest management. | **4.1.e** Area and per cent of forest land with significant compaction or change in soil physical properties resulting from human activities. |
| **3.1.a** Area and per cent of forest affected by processes or agents that may change ecosystem health and vitality. (A narrative as interim) | | **4.1.f** Per cent of water bodies in forest areas (e.g. stream kilometres, lake hectares) with significant variance of biological diversity from the historic range of variability. |
| **4.1.a** (Interim) Area and per cent of forest land systematically assessed for soil erosion hazard, and for which site-varying scientifically-based measures to protect soil and water values are implemented. | | **6.1.b** Value and quantities of production of non-wood forest products. |
| **6.2.c** Number of visits per annum. | | **6.2.b** Number, range and use of recreation/tourism activities available in a given region. |
| **6.5.a** Direct and indirect employment in the forest sector and forest sector employment as a proportion of total employment. (Direct) | | **6.5.c(i)** Viability and adaptability to changing social and economic conditions of forest dependent communities. |
| **7.1** (Narrative) *Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests.* | | **6.5.c(ii)** Viability and adaptability of forest dependent Indigenous communities. |
| **7.2** (Narrative) *Extent to which the institutional framework supports the conservation and sustainable management of forests.* | | |
| **7.4** (Narrative) *Capacity to measure and monitor changes in the conservation and sustainable management of forests.* | | |
| **7.5** (Narrative) *Capacity to conduct and apply research and development aimed at improving forest management and delivery of forest goods and services.* | | |
| **Total: 12 indicators & 4 sub-criteria** | **Total: 8 indicators** | **Total: 13 indicators** |

# CALM WORKSHOP

## Integrated Forest Monitoring System Concept Plan

### 7-8 April 1999

| Division | Invited | Attended |
|---|---|---|
| CALM**Science** | I Abbott | ✓ |
| | N Burrows | ✓ |
| | S Halse | ✓ |
| | G Liddelow | ✓ |
| | N Marchant | ✓ |
| | J McGrath | ✓ |
| | K Morris | N McKenzie |
| | R Robinson | ✓ |
| | A Wayne | X |
| | M Yung | ✓ |
| Management Audit | P Jones | ✓ |
| Corporate Services | R Fieldgate | ✓ |
| | C Pearce | X |
| Regional Services | B Chandler | K Williams |
| | B Harvey | K Low |
| | P Keppel | X |
| Forest Resources | P Collins | ✓ |
| | J Murch | M Buckton |
| | M Rayner | ✓ |
| | A Seymour | X |
| Nature Conservation | R Armstrong | ✓ |
| | G Wyre | P Orell |
| Independent | J Bradshaw | ✓ |
| | P Christensen | ✓ |

# CALM Integrated Forest Monitoring System Implementation Group

Ian Abbott (Chair)

John McGrath

Roger Hearn

Graeme Liddelow

Colin Pearce

# EXTERNAL WORKSHOP

## Integrated Forest Monitoring System Concept Plan

**28 October 1999**

| Institution | Invited | Attended |
|---|---|---|
| Murdoch University | Dr Stuart Bradley | X |
| | Dr Jenny Davis | ✓ |
| | Ms Karen Strehlow | ✓ |
| | A/Prof Bernie Dell | ✓ |
| | A/Prof Ron Wooller | ✓ |
| | Dr Mike Calver | ✓ |
| Edith Cowan University | Dr Pierre Horwitz | ✓ |
| | Prof Harry Recher | ✓ |
| Curtin University | Prof Byron Lamont | X |
| | Prof Jonathan Majer | ✓ |
| University of WA | A/Prof Mark Adams | ✓ |
| | Prof Don Bradshaw | X |
| | Dr Dale Roberts | ✓ |
| | Dr Andrew Storey | ✓ |
| CSIRO | Dr Neale Bougher | ✓ |
| | Dr Richard Hobbs | ✓ |
| | Dr Robert Lambeck | X |
| Independent | Dr Mike Bamford | ✓ |
| | Dr David Bell | X |
| | Dr Per Christensen | ✓ |
| | Mr Joe Havel | ✓ |
| | Dr Barbara Main | ✓ |
| | Dr Libby Mattiske | ✓ |
| | Dr Owen Nichols | ✓ |
| DEP | Mr Colin Murray | ✓ |
| Kings Park & Botanic Garden | Dr Steve Hopper | ✓ |
| WA Museum | Dr Ric How | ✓ |
| | Dr Mark Harvey | X |
| | Dr Ken Aplin | X |
| CALM | Mr Alan Walker | X |
| | Mr Roger Hearn | ✓ |
| | Dr Colin Pearce | ✓ |
| | Dr Ian Abbott | ✓ |
| | Dr Neil Burrows | ✓ |
| | Mr Graeme Liddelow | ✓ |
| | Dr Neville Marchant | ✓ |
| | Dr John McGrath | ✓ |
| | Mr Keith Morris | ✓ |
| | Mr Matthew Williams | ✓ |

# EXTERNAL WORKSHOP

## Integrated Forest Monitoring System Concept Plan

**16 March 2000**

| Institution | Invited | Attended |
|---|---|---|
| Murdoch University | Dr Mike Calver | ✓ |
| | Dr Jenny Davis | X |
| | A/Prof Bernie Dell | X |
| | Prof I Potter | X |
| | Ms Karen Strehlow | X |
| | A/Prof Ron Wooller | X |
| Edith Cowan University | Dr Pierre Horwitz | X |
| | Prof Harry Recher* | X |
| Curtin University | Prof Byron Lamont | X |
| | Prof Jonathan Majer | ✓ |
| University of WA | A/Prof Mark Adams | ✓ |
| | Dr Dale Roberts | ✓ |
| | Dr Andrew Storey | ✓ |
| CSIRO | Dr Neale Bougher | ✓ |
| | Dr Richard Hobbs | ✓ |
| Independent | Dr Mike Bamford* | X |
| | Dr Per Christensen | ✓ |
| | Mr Joe Havel | ✓ |
| | Dr Barbara Main | X |
| | Dr Libby Mattiske | X |
| | Dr Owen Nichols | X |
| DEP | Mr Colin Murray | ✓ |
| Kings Park & Botanic Garden | Dr Steve Hopper | X |
| WA Museum | Dr Ric How | X |
| | Dr Mark Harvey | X |
| Water & Rivers Commission | Dr Luke Pen | X |
| CALM | Dr Ian Abbott | ✓ |
| | Dr Neil Burrows | ✓ |
| | Dr David Coates | ✓ |
| | Dr Janet Farr | ✓ |
| | Mr Roger Hearn | ✓ |
| | Dr Stuart Halse | ✓ |
| | Mr Jim Lane | X |
| | Mr Joe Kinal | ✓ |
| | Mr Graeme Liddelow | ✓ |

| Institution | Invited | Attended |
|---|---|---|
| | Dr Neville Marchant | ✓ |
| | Dr Lachie McCaw* | X |
| | Dr John McGrath | ✓ |
| | Mr Keith Morris | N McKenzie |
| | Dr Colin Pearce | X |
| | Dr Richard Robinson | ✓ |
| | Dr Bryan Shearer | ✓ |
| | Dr Geoff Stoneman | ✓ |
| | Mr Bruce Ward | ✓ |
| | Mr Adrian Wayne | ✓ |

*provided written comment on draft document

**TO: All persons who attended one or both of the external workshops**

**INTEGRATED FOREST MONITORING SYSTEM: CONCEPT PLAN**

The draft discussed at the workshop held at Technology Park in March 2000 has now been revised, ready for submission to CALM's Corporate Executive for its consideration.

The October and March workshops provided much valuable advice and assistance in remedying defects in the concept plan. I am also grateful to those who sent in written comment on the document, drawing my attention to mistakes and some unclear portions of the document.

There remain, however, a few suggestions that I am unable to accept. I now list these and provide a brief comment or justification for not accepting this advice. All references are to the draft issued in, and dated, December 1999.

1. Page 7. The sampling design set out was misinterpreted by several participants as being an ANOVA experiment. This was not our intention and the text has been revised.
2. Page 8. Various suggestions were made about changing the plot or quadrat size for sampling plots. The sampling scheme outlined in the concept plan adheres to that operating in the Kingston study. I believe that IFMS should align so far as possible with the detailed research conducted at Kingston.
3. Page 9. It was suggested that a 1 ha plot is too small for sampling jarrah forest birds. This plot size is based on the PhD research of M Craig and is constrained by the 10 ha size of areas cut to gaps. It is important that the census plot has a generous buffer.
4. Page 9. It was suggested that pitfalls for capturing mammals, reptiles and frogs should be filled with glycol and left operative for several months. This is to maximize the sampling of frogs and reptiles, which have episodic pulses in activity related to particular weather conditions. These pulses are unlikely to be detected with sporadic sampling.

   This suggestion has not been adopted because of my concerns that such a procedure of killing all animals pitfalled may compromise future monitoring. I am also concerned about the ethics of killing animals for this purpose.
5. Page 10. Aquatic invertebrates. Advice provided at the March workshop was that there were no suitable indicator species and that an intensive biological survey of streams throughout the jarrah forest was required. This issue has therefore been "parked" on p.7 under section (ix) of the plan submitted to Corporate Executive. I also await with interest the results of the AUSRIVAS research program.
6. Page 11. Statistical interpretation of change. The point raised at both workshops concerning statistical power is accepted. However, it was generally overlooked that with adaptive management there is ongoing collection and analysis of data, so that over time replication will increase. It is thus considered premature to criticize IFMS because of our current inability to estimate power for all but a few taxa.
   In addition, data will also be analysed using ordination techniques for which power considerations are not relevant.
7. Page 14. The graph presented was criticized on the ground that it did not fit one particular data set. However, the text on p.13 made it clear that the graph was a generalized expectation of results and thus was only hypothetical.

Once IFMS is established, my intention is to set up small taxon-based working groups so that interim results can be interpreted by experts in CALM, CSIRO, universities etc.

Thank you for participating in this process. Your input is valued.

Yours sincerely

Dr Neil Burrows
DIRECTOR
CALM**Science** Division